UNIVERSITY OF WISCONSIN SYSTEM

The University of Wisconsin System (UWS) maintains groundwater-related research, teaching, and outreach responsibilities. These three missions are integrated through cooperation and joint appointments of research, education, and outreach and extension personnel, along with postgraduate fellows, who address groundwater issues. UWS staff members work with state and federal agencies and other partners to solve groundwater resources issues. Research is coordinated through the University of Wisconsin Water Resources Institute, which conducts annual calls for proposals followed by rigorous peer and panel review of the proposed projects. Typically, four to seven projects are funded through the Institute each year. Citizen outreach is accomplished through publications, video and audio podcasts, social media, media relations, public meetings and presentations, teleconferences, and water testing and satellite programs. In the following sections, we describe the activities of several university programs, including the *University of Wisconsin Water Resources Institute*, the *Central Wisconsin Groundwater Center* (affiliated with UW-Madison's Division of Extension and UW-Stevens Point), the *Natural Resources Institute's Land and Water Programs* at UW-Madison's Division of Extension, the *University of Wisconsin Nutrient and Pest Management Program*, and the *Wisconsin State Laboratory of Hygiene*.

Details of Ongoing Activities:

University of Wisconsin Water Resources Institute (WRI)

The University of Wisconsin Water Resources Institute (WRI) is one of 54 water resources institutes located on universities across the nation with core funding provided and administered by the U.S. Department of the Interior through the U.S. Geological Survey. The Institute promotes research, training, and information dissemination focused on Wisconsin's and the nation's water resources problems. WRI is a UWS program administratively housed at UW-Madison's Aquatic Sciences Center, along with the University of Wisconsin Sea Grant College Program.

FY 2022 Highlights

- In support of the Wisconsin Groundwater Research and Monitoring Program, provided UWS funding to seven research projects focused on groundwater contaminants, including nitrate, radium, strontium and road salt; water quantity challenges in the Central Sands; geochemistry and microbiology; groundwater-surface water interactions; and economics of groundwater and water utilities and supported graduate and undergraduate students at UW-Milwaukee, UW-Madison, UW-Stevens Point, and UW-Platteville.
- Coordinated the Request for Proposals and the review process for the FY23 Joint Solicitation for the Wisconsin Groundwater Research and Monitoring Program.
- Supported five Water Resources Science-Policy post graduate fellows in partnership with the Wisconsin Department of Natural Resources (DNR), Wisconsin Department of Health Services (DHS), and University of Milwaukee Center for Water Policy to work on state priority groundwater and surface water challenges, including completion of a legislatively requested study on water in the Central Sands Region,

development of decision-support tools for high-capacity wells, the effect of a changing climate on brook and brown trout, and statewide public health tracking for harmful algal bloom toxin exposure. It also leveraged Aquatic Sciences Center funding to support ten additional post graduate fellows working on aquatic toxicology and PFAS, community flood resiliency, coastal hazards, coastal wetlands, and aquaculture.

- Organized and conducted a statewide workshop among university researchers and state scientists, resource managers and policymakers to determine gaps in understanding per- and polyfluoroalkyl (PFAS) in Wisconsin. This was in partnership with the State Laboratory of Hygiene and the University of Wisconsin Sea Grant College Program. A *white paper* from the workshop will assist in setting future priorities.

Per- and polyfluoroalkyl substances (PFAS) are chemicals used in everyday items like clothing and cookware. They can accumulate in fish, wildlife, and humans. Here, a Water Resources Institute-funded researcher is studying analyzing chemicals in her lab. *Photo: Bonnie Willison*

- In early summer 2022, kicked off the inaugural cohort of summer undergraduate research experiences for those on University of Wisconsin System campuses. The freshwater science explorations will pair students with researchers at campuses at Eau Claire, La Crosse, Madison, and Platteville. In future years, the program will expand to other campuses. It is funded by the Freshwater Collaborative, WRI and the Sea Grant College Program.
- Supported the annual Wisconsin Chapter of the American Water Resources Association meeting. This year, the Wisconsin Water Library and the Wisconsin Geological and Natural History Survey also collaborated to post digital copies of the meetings' proceedings from 1978 to the present on a University of Wisconsin-Madison library *website*. This will make the water science material widely available.
- Produced seven episodes of a podcast called *Wisconsin Water News* that explores relevant water topics through this easily downloadable and informative tool.

- Supported the production of 27 final project reports, 15 theses, and 87 peer-reviewed publications over the past five years.

Research

The WRI research portfolio is supported by UW System funding for the Wisconsin Groundwater Research and Monitoring Program and includes interdisciplinary projects in four areas: groundwater, surface water, groundwater-surface water interactions, and drinking water. Groundwater is a top priority and an area of particular strength at the WRI.

During FY22, the WRI directed a wide-ranging program of priority groundwater research consisting of four new projects and three continued projects. These included short- and long-term studies both applied and fundamental in nature. They provide a balanced program of laboratory, field, and computer-modeling studies and applications aimed at preserving or improving groundwater quality and quantity. Key areas of emphasis in FY22 included research focused on groundwater contaminants, including nitrate, radium, strontium, and road salt; water quantity challenges in the Central Sands; geochemistry and microbiology; groundwater-surface water interactions; and economics of groundwater and water utilities and supported graduate and undergraduate students at UW-Milwaukee, UW-Madison, UW-Stevens Point, and UW-Platteville.

Undergraduate assistant Dylan A. Childs completing chloride analysis using the chloride probe in University of Wisconsin-Milwaukee Paradis Lab, summer 2021. The project is funded by WRI.

Groundwater issues investigated during the past year included:

- Investigating in-season cover crops for reducing nitrate loss to groundwater below potatoes. Kevin Masarik and Jacob Prater, UW-Stevens Point. (continuing)
- Valuing groundwater quality: A cost function analysis of Wisconsin water utilities. James Price, UW-Milwaukee. (continuing)
- Investigating sources of salinity associated with Ra and Sr in the Cambrian-Ordovician aquifer system of eastern WI. Matthew Ginder-Vogel, Patrick Gorski, and Sean Scott, UW-Madison and Wisconsin State Laboratory of Hygiene. (continuing)
- Measurement of bacterial transport and immobilization in variably saturated geologic materials of WI. Christopher Zahasky, Eric Roden and Vy Le, UW-Madison. (new)
- Mass discharge of road salt via groundwater to surface waters in Southeastern Wisconsin. Charles Paradis, Laura Herrick, Cheryl Nenn, and Timothy Wahl, UW-Milwaukee and Southeast Wisconsin Regional Planning Commission. (new)
- Data-driven groundwater depth and risk forecasting in the Central Sands region of WI for sustainable management. Jingji Huang and Ankur Desai, UW-Madison. (new)
- Assessment of biochar application to reduce nitrate leaching through agricultural vegetative treatment areas. Joseph Sanford, UW-Platteville. (new)

For FY23 (July 1, 2022 - June 30, 2023), the UWS selected two new groundwater research projects from proposals submitted in response to the Joint Solicitation for Wisconsin Groundwater Research and Monitoring Program and will continue four projects selected from the previous years' solicitations. The projects are based at UW-Madison and include:

- Aligning the Wisconsin Idea on water: Interpreting public perspectives and values. Michael Cardiff, Ken Genskow, and Bret Shaw, UW-Madison. (new)
- Biomanipulation of Groundwater Flooding. Steven Loheide II, Kenneth Potter, UW-Madison. (new)

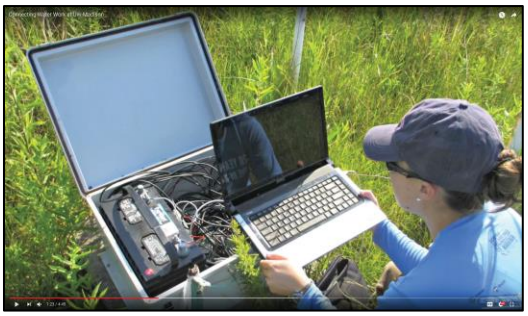
Additionally, the WRI receives an annual federal 104(B) allocation that can be used to advance groundwater and other water resources research and initiatives. This allocation is

often used to fully support or augment a project selected through the state groundwater competition, freeing up state resources to invest in additional strong proposals submitted to the groundwater competition. In FY22, this allocation supported:

- Fate of groundwater phosphorus from septic systems near lakes. Paul McGinley, UW-Stevens Point. (continuing)

In addition, this federal allocation was matched by state agency partners and used to:

- Support a Water Resources Science-Policy postdoctoral fellow in partnership with DNR's Drinking Water and Groundwater Program to work on the Central Sands Lakes Study (study requested by the legislature). (Dr. Carolyn Voter, 2019-21).
- Support a Water Resources Science-Policy postdoctoral fellows in partnership with DNR's Fisheries Management Program to work on the state's streamflow model and effects of stream hydrology on fisheries. (Dr. Bryan Maitland, 2020-22).
- Recruit and support a Water Resources Science-Policy postdoctoral fellow in partnership with DHS to work on public health aspects of harmful algal bloom toxin exposure (Jordan Murray, 2021-22).
- Recruit and partially support two Water Resources Science-Policy legal fellows placed at the UW-Milwaukee Center for Water Policy to work on water policy and equity issues (Misbah Husain and Sarah Martinez, 2021-22)



Pictured is Dr. Carolyn Voter, one of WRI's Wisconsin Water Resources Science-Policy Postdoctoral Fellows, who was integral to the 2021 Central Sands Lake Study Report, as directed by the legislature.

Lastly, the Aquatic Sciences Center (home to WRI) successfully secured a grant from the U.S. Environmental Protection Agency to support three UW-U.S. Environmental Protection Agency Human Health and the Environment Postdoctoral Research Fellows. (Drs. Nathan Pollesch, Prarthana Shankar, and Sally Mayasich, 2019-22). And, through a variety of partnerships, the Aquatic Sciences Center was also able to support post graduate fellows to work on PFAS contamination of surface waters (Dr. Sarah Balgooyen, 2019-22), community flood resiliency (Jackson Parr, DHS, 2021-22), coastal hazards (Lydia Salus, Emily Rau, and Sarah Brown, Department of Administration, 2019-22), coastal wetlands (Dr. Nicole Ward, DNR, 2021-22), and aquaculture (Dr. Patrick Blaufuss, UW-Stevens Point and Milwaukee, 2020-22).

Teaching

Institutions within the UWS continue to offer undergraduate- and graduate-level courses and opportunities focusing on diverse issues regarding groundwater resources. Additionally, several campuses offer for-credit, field-oriented water curriculum courses for middle- and high school teachers during summer sessions. The WRI also views continuing education for P-12 teachers as an important component of its outreach and training effort. The Wisconsin Water Library, housed on the UW-Madison campus and funded by the WRI, maintains an extensive collection of curricula with innovative approaches and other educational materials for teaching water-related science in P-12 classrooms. Through the librarian's outreach to teachers last year, nearly 20,000 students were exposed to water-

science learning. The library's curricula are available for checkout by all teachers and residents in Wisconsin. The librarian also has deep experience in working with children. She put that experience to use in developing kits based on field-tested science, technology, engineering, art, and math. The kits will eventually number 27 on topics such as the water cycle, art and water, and pond science. The kits contain several books, directions for a guided science experiment and other themed activities. Finally, the library provides checkout of an aquatic invasive species elementary and middle school curriculum collection known as an attack pack. The packs have been used to educate people about aquatic invasive species in the waters of Wisconsin and are being updated to include additional information about fish.

Grants Administration

The WRI conducts the annual outside peer review of all proposals submitted to the state of Wisconsin Joint Solicitation for Groundwater Research and Monitoring. In FY22, WRI continued to use a web-based proposal submission, review, and reporting system *eDrop*. The website enables seamless online submission and review of proposals. At the site, prospective investigators submit a proposal by filling out a series of forms and uploading their full proposal and budget. Assigned reviewers then complete their reviews through eDrop by answering a series of questions online. Once all the reviews are completed, the UW Groundwater Research Advisory Council is granted access to anonymous reviews and original proposals to help decide which proposals to recommend for funding. Agency partners also have access to the reviews to inform their selection processes as well. The website provides a framework for consistently capturing the same information from all the prospective investigators and reviewers, ensuring all proposals are treated equally.

Information-Sharing and Outreach Activities

The *University of Wisconsin Water Resources Institute website* offers research projects and publications. One of the site's main audiences is researchers. To that end, the site provides a clear navigational path to the WRI project listings, project reports, a groundwater research database, funding opportunities, and conference information sections. All of these areas are updated on a regular basis to ensure currency of information transfer. Additionally, WRI has a presence on Twitter, Facebook, and Flickr.

Video is a compelling way to share water-science information. The Institute's video catalog includes seven titles. The most popular one is "Testing well water for microorganisms." To date it has more than 13,000 views, which is a large number for a scientific topic.

The Pew Research Center, in a 2017 report, noted that the percentage of podcast listeners in America has substantially increased since 2006. At the time of the report, four in ten Americans ages 12 or older had listened to a podcast and 24 percent had listened to a podcast in the past month, up from just 9 percent in 2008. WRI capitalizes on this popular platform. It offers five multi-part *podcast* series on topics such as groundwater, mercury in aquatic environments, and aquifers and watersheds.

During this reporting period, WRI staff were integral to the leadership and content-population of Water@UW-Madsion located here - *https://water.wisc.edu/*. The site is a portal to the breadth and depth of water-related work on the state's flagship campus, the

UW-Madison, and serves as the first stop for anyone interested in water research. Graduate students can search for departments offering courses and degrees that fit their interests. Prospective graduate students can use the site to investigate potential faculty advisors. Finally, staff and faculty can search for colleagues working on topics complementary to their own to facilitate greater interdisciplinary collaboration and efficiencies. This year, Institute Associate Director Dr. Jennifer Hauxwell advised the Water@UW-Madison executive committee. Natalie Chin, the Institute's tourism and climate change specialist, and Moira Harrington, the Institute's communications lead, served on the committee. The group hosted a spring event that reached hundreds of viewers. Additionally, WRI Director Jim Hurley serves on the Steering Committee for the Freshwater Collaborative, another entity promoting collaboration, this time among University of Wisconsin System campuses.

Water Resources Publications

The program offers easily accessible publications through an *online site*, with free information or information available for a nominal cost. Topics include nitrates in groundwater, siting rain gardens, and arsenic in groundwater. The program also produces the *Aquatic Sciences Chronicle* on a quarterly basis. It circulates to roughly 5,500 electronic and print subscribers with an interest in WRI projects and related topics. The newsletters are also posted online.

Wisconsin's Water Library

Wisconsin's Water Library is a unique resource for Wisconsin citizens. It contains more than 30,000 volumes of water-related information about the Great Lakes and the waters of Wisconsin. The library includes a curriculum collection, dozens of educational videos, a children's collection, and more than five journals and 30 newsletters.

In addition to archival benefits, the library provides outreach by answering many in-depth reference questions on a wide range of water-related topics. In partnership with the Wisconsin Department of Natural Resources and the Wisconsin Wastewater Operator's Association (WWOA), the library offers assistance to current and future wastewater and drinking water operators of Wisconsin. The library catalogs the essential technical manuals and loans them to WWOA members around the state in support of required state license examinations.

Wisconsin's Water Library continues to catalog all groundwater research reports from projects funded by the WRI into WorldCat and MadCat, two library indexing tools that provide both worldwide and statewide access to WRI research. By having this information permanently indexed, the research results are easily available to other scientists throughout the University of Wisconsin System as well as across the nation and the world.

The library also maintains a digital archive of the entire collection *of Groundwater Research and Monitoring Program reports.* The archive was created in partnership with the UW Digital Collections Center and ensures a permanent and accessible electronic record of Wisconsin groundwater-related activities since 1984. Paper copies of the reports continue to be a part of the Wisconsin Water Library.

Technical Research Publications Resulting From Recent WRI Groundwater Research and Monitoring Program-Sponsored and Other WRI-Supported Projects (Past Five Years):

Water Resources Institute Reports

Bahr, J., M. Gotkowitz, and J. Olson. 2017. Long-term alterations in groundwater chemistry induced by municipal well pumping. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 16p. WR15R002.

Booth, E. G., S. P. Loheide II, D. Bart, P. A. Townsend, and A. C. Ryzak. 2019. Linking groundwater and nutrients to monitor fen ecosystems using airborne imaging spectroscopy. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 20p. WR17R001/2018WI372B.

Choi, C.Y., D.J. Hart, J.M. Tinjum, and M.K. Harper. 2016. Assessment of environmental impacts of geothermal source heat exchange. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 22p. WR14R002.

Choi, W., and C. Wu. 2016. Impacts of climate and land use changes on streamflow and water quality in the Milwaukee River Basin. (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 17p. WR13R004/2013WI314B.

Ginder-Vogel, M., and C. Remucal. 2016. Effect of source chemistry on Mn-bearing solid dissolution and reactivity in municipal water systems. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 14p. WR14R004/2015WI335B. WR15R009.

Grundl, T., L. Fields-Sommers, and J. Graham. 2016. Groundwater-surface water interactions caused by pumping from a riverbank inducement well field. (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 23p. WR13R002/2013WI319O.

Grundl, T., R. Newton, N. Gayner, and M.J. Salo. 2020. Anthropogenically driven changes to shallow groundwater in southeastern Wisconsin and its effects on the aquifer microbial communities. (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 36p. WR16R001.

Hauxwell, J. 2016. Wisconsin Water Resources Fellowship. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 3p. WR15R006/2015WI325B.

Kucharik, C.J., T. Campbell. 2020. Improving water and nitrogen use efficiency under changing weather variability in the Central Sands. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 18p. WR18R001.

Lark, T., and Y. Xie. 2020. Mapping annual irrigation extent at 30-m resolution across the United States, 1997-2017. (University of Wisconsin-Madison). Final Report, UW-USGS Irrigation Mapping Project. 60 pp. G19AC00080/2016WI354G.

Larson, E.R., and S.A. Allen. 2016. Establishing the long-term range of variability in drought conditions for southwest Wisconsin. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 17p. WR13R003/2013WI313B.

Loheide, S., and D. M. Ciruzzi. 2019. Historic changes in groundwater use by trees in Wisconsin due to high-capacity groundwater pumping and climate variability. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. WR17R002.

McIntyre, P.B. 2016. Climate change impacts on stream temperature and flow: consequences for Great Lakes fish migrations. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 14p. WR11R002/2011WI267B.

McLellan, S. 2021. Detection of Sewage Contamination in Urban Areas of the Great Lakes. . (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 3 pp. WR16R005/2016WI354G.

Nitka, A., P. McGinley. 2017. Investigating the impact of nitrate contamination on uranium and other elements of emerging concern in Wisconsin groundwater. (University of Wisconsin-Stevens Point). Final Report, University of Wisconsin Water Resources Institute. 16p. WR16R002.

Noguera, D. M. Anderson, I. Tejedor, J. Wouters. 2017. Phosphorus and arsenic sensors for real time environmental monitoring. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 15p. WR15R001.

Plank, E., H. Yang, X. Min, Y. Wang, S. Xu. 2020. Dynamics of arsenic concentration and speciation in Wisconsin private drinking water wells. (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 32p. WR18R002.

Remucal, C. 2020. The impact of dissolved organic matter composition on the formation of disinfection byproducts in groundwater. (University of Wisconsin-Madison). Final Report, Final Report, University of Wisconsin Water Resources Institute. 18p. WR18R003.

Scherber, K.S., and S.P. Loheide. 2017. Hydraulic impacts of the loss of Wisconsin's winter on surface water – groundwater interactions. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 16p. WR14R003.

Stelzer, R., and T. Scott. 2017. Predicting the locations of nitrate removal hotspots at the groundwater-surface water interface in Wisconsin streams. (University of Wisconsin-Oshkosh). Final Report, University of Wisconsin Water Resources Institute. 22p. WR15R003.

Stewart, E.D., W. Fitzpatrick, E.K. Stewart. 2021. Correlating bedrock folds and fractures to arsenic detection in drinking water, southeast Wisconsin. WR20R004

Stewart, E.K., J. Rasmussen, J. Skalbeck, L. Brengman, M. Gotkowitz. 2018. Mapping the base of the Cambrian aquifer through geophysical modeling of Precambrian topography, southern Wisconsin. (University of Wisconsin-Extension). Final Report, University of Wisconsin Water Resources Institute. 15p. WR17R003.

Ventura, S., and S. Cardiff. 2016. Advances in monitoring and analysis of trace metals: a workshop to address applications in the Upper Great Lakes. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 15p. WR14R001/2014WI325B.

Vitale, S., J.B. Mahoney, A. Baker. 2020. Assessment of the source and mobility of phosphorus in the hydrologic system in western Wisconsin. (University of Wisconsin-Eau Claire). Final Report, Final Report, University of Wisconsin Water Resources Institute. 19p. WR19R002.

Vitale, S., J.B. Mahoney, A. Baker. 2021. Source to sink evaluation of phosphorus in the hydrologic system in Wisconsin: Implications for lake eutrophication. Final Report, University of Wisconsin Water Resources Institute. 17 pp. WR20R003.

Wu, C. 2016. Uncertainty and variability of Wisconsin lakes in response to climate change. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 19p. WR11R003/2011WI268B.

Zambito IV, J.J., L.D. Haas, M.J. Parsen, and P.I. McLaughlin. 2016. The Wonewoc and Tunnel City: A potential natural source of groundwater contamination in west-central Wisconsin. (University of Wisconsin-Extension). Final Report, University of Wisconsin Water Resources Institute. 51p. WR15R004.

Theses

Cardiff, Scott. 2016. Cumulative land cover and water quality impacts of large-scale mining in Lake Superior Ojibwe Treaty-ceded Territories. Ph. D. Thesis. Nelson Institute, University of Wisconsin-Madison, Madison, WI. WR14R001/2014WI325B.

Fields-Sommers, Laura. 2016. Assessing the effects of riverbank inducement on a shallow aquifer in southeastern Wisconsin. M.S. Thesis. Freshwater Sciences and Technology, UW –Milwaukee, Milwaukee, WI. 211p. WR13R002/2013WI319O.

Gayner, Natalie June. 2018. River Bank Inducement Influence on a Shallow Groundwater Microbial Community and Its Effects on Aquifer Reactivity. M.S. Thesis. Freshwater Science. University of Wisconsin - Milwaukee. *https://dc.uwm.edu/etd/1990*. WR16R001.

Haas, Lisa. 2021. Microbially-Mediated Oxidation of Trace Element-Bearing Sulfide Minerals in Sandstones of Trempealeau County, WI. MS Thesis. Geosciences. University of Wisconsin-Madison. WR19R001.

Hamby, A., 2018. The effects of faults and changing water levels on confined sandstone aquifer water chemistry in northeastern Wisconsin. MS Thesis. University of Wisconsin-Green Bay, Green Bay, WI. WR12R004/2013WI329O.

Hyman-Rabeler, Katrina. 2021. Impacts of Changing Frozen Ground Regimes on Groundwater Recharge. MS Thesis. 160 pp. Geological Engineering, University of Wisconsin-Madison. WR19R005/2020WI308B.

Lepak, R. 2018. Multidimensional Tracing of Mercury Sources and Bioaccumulation Pathways Using Stable Isotopic Analyses. PhD Thesis. Environmental Chemistry and Technology. University of Wisconsin - Madison. WR18R005.

Li, Wenliang. 2016. Large-scale urban impervious surfaces estimation through incorporating temporal and spatial information into spectral mixture analysis. Ph.D. Thesis. Department of Geography, University of Wisconsin-Milwaukee, Milwaukee, WI. 110p. WR13R004/2013WI314B.

Magee, Madeline. 2016. Simulation of lake thermal structure, ice cover, and fish habitat in response to changing climate. Ph. D. Thesis. Civil and Environmental Engineering, UW-Madison, Madison, WI. 171p. WR11R003/2011WI268B.

Michaud, 2018. Long term performance of radon barrier in limiting radon flux from four uranium mill tailings containment facilities. MS Thesis, Geological Engineering, University of Wisconsin-Madison. WR13R004/2013WI314B.

Peterson, Benjamin. 2021. Ecophysiology of mercury-methylating microorganisms in freshwater ecosystems. Ph.D. Thesis. 218 pp. Environmental Chemistry and Technology, University of Wisconsin-Madison. WR19R006/2019WI001G.

Plank, Evvan. 2019. The Dynamics and Speciation of Arsenic in Drinking Water Wells in Eastern Wisconsin. M.S. Thesis. Geosciences. University of Wisconsin - Milwaukee. *https://dc.uwm.edu/etd/2328*. WR18R002.

Salo, Madeline Jean. 2019. Anthropogenically Driven Changes to Shallow Groundwater in Southeastern Wisconsin and Its Effects on the Aquifer Microbial Communities. M.S. Thesis. Geosciences. University of Wisconsin - Milwaukee. *https://dc.uwm.edu/etd/2116*. WR16R001.

Stefani, Nick. 2016. *Field and laboratory measurement of radon flux and diffusion for uranium mill tailings cover systems*. M.S. Thesis. Geological Engineering, UW-Madison, Madison, WI. 98p. WR15R008/2015WI359S.

Voter, Carolyn. 2019. Hydroecologic Effects of Urban Development Decisions in Residential Areas. Doctoral dissertation. University of Wisconsin-Madison, Madison, WI. WR12R002/2013WI327O.

Other Publications

Balgooyen, S. P.J. Alaimo, C.K. Remucal, and M. Ginder-Vogel. 2017. Structural transformation of MnO_2 during the oxidation of bisphenol A. Environmental Science & Technology 51:6053-6062. DOI: 10.1021/acs.est.6b05904. WR14R004/2015WI335B. WR15R009.

Barker D, DeMaria A, Caraco D, Corsi S, Kinzelman J, Liner B, McLellan S, McFadden L, Nenn C. 2019. Detection of Wastewater Contamination - Knowledge Development Forum. Water Environment Federation, Water Science & Engineering Center, WSEC-2019-KDF_TR-001. WR16R005/2016WI354G.

Benson, C.H., W.H. Albright, M. Fuhrman, W.J. Likos, N. Stefani, K. Tian, W.J. Waugh, and M.M. Williams. 2017. Radon fluxes from an earthen barrier over uranium mill tailings after two decades of service. Proc. WM2017 Conference, March 5-9, 2017, Phoenix, Arizona, USA. WR13R004/2013WI314B.

Bero, N.J., M.D. Ruark, and B. Lowery. 2016. Bromide and chloride tracer application to determine sufficiency of plot size and well depth placement to capture preferential flow and solute leaching. Geoderma 262:94-100. *https://doi.org/10.1016/j.geoderma.2015.08.001*. WR10R004/2010WI283O.

Bradbury, K., J.A. Hauxwell, M. Zhuikov. 2021. The Wisconsin Groundwater Coordinating Council: 37 years of state agency cooperation. Groundwater. Guest Editorial. *https://doi.org/10.1111/gwat.13141*.

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Childress, E.S., and P.B. McIntyre. 2016. Life history traits and spawning behavior modulate ecosystem-level effects of nutrient subsidies from fish migrations. Ecosphere 7:e01301. 10.1002/ecs2.1301. WR11R002/2011WI267B.

Choi, W., F. Pan, and C. Wu. 2017. Impacts of climate change and urban growth on the streamflow of the Milwaukee River (Wisconsin, USA). Regional Environmental Change 17:889-899. doi:10.1007/s10113-016-1083-3. WR13R004/2013WI314B.

Ciruzzi, D.M., S.P. Loheide II. 2021. Groundwater subsidizes tree growth and transpiration in sandy humid forests. Ecohydrology. *https://doi.org/10.1002/eco.2294*. WR17R002.

Corsi, S.R., L.A. De Cicco, A.M. Hansen, P.L. Lenaker, B.A. Bergamaschi, B.A. Pellerin, D.K. Dila, M.J. Bootsma, S.K. Spencer, M.A. Borchardt, and S.L. McLellan. 2021. Optical properties of water for prediction of wastewater contamination, human-associated bacteria, and fecal indicator bacteria in surface water at three watershed scales. Environmental Science & Technology 55:13770-13782. WR16R005/2016WI354G.

Dematatis, M., A. Plechacek, M. Mathews, D.B. Wright, F. Udenby, M.B. Gotkowitz, and M. Ginder-Vogel. 2020. Spatial and temporal variability of radium in the Wisconsin Cambrian-Ordovician aquifer system. AWWA Water Science. *https://doi.org/10.1002/aws2.1171*.

Deng, Y. and C. Wu. 2016. Development of a class-based multiple endmember spectral mixture analysis (CMESMA) approach for analyzing urban environments. Remote Sensing 8:349. *https://doi.org/10.3390/rs8040349*. WR13R004/2013WI314B.

Federman, T., et al. 2017. Developing new tree-ring chronologies from eastern redcedar (Juniperus virginiana) to seek insight to variations in groundwater resources in central Wisconsin. Proceedings of the Annual Meeting of the American Association of Geographers, Online Abstracts and Programs. WR17R004.

Feiner, Z.S., A.D. Shulz, G.G. Sass, A. Trudeau, M.G. Mitro, C.J. Dasso, A.W. Latzka, D.A. Isermann, B.M. Maitland, J.J. Homola, H.S. Embke, M. Preul. 2022. Resist-accept-direct (RAD) considerations for climate change adaptation in fisheries: the Wisconsin experience. Fisheries Management and Ecology 00:1-18. *https://doi.org/10.1111/fme.12549*. WR19R007/2020WI294B

Fuhrmann, M., C. Benson, J. Waugh, M. Williams, and H. Arlt. 2019. Proceedings of the Radon Barriers Workshop July 25–26, 2018, NRC Headquarters, Rockville, MD. US Nuclear Regulatory Commission, NUREG/CP-0312. WR15R008/2015WI359S.

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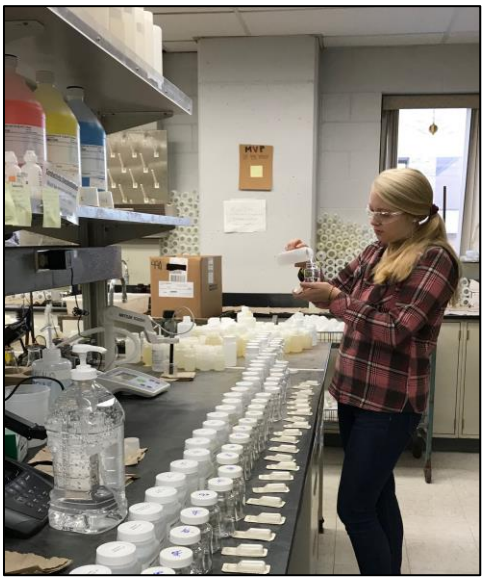
Central Wisconsin Groundwater Center

The *Central Wisconsin Groundwater Center* is an affiliate of the Center for Watershed Science and Education. It is a partnership between the College of Natural Resources at the University of Wisconsin – Stevens Point and the University of Wisconsin – Madison, Division of Extension. The Central Wisconsin Groundwater Center provides groundwater education, research and technical assistance to the citizens and governments of Wisconsin. Assistance includes answering citizen questions, helping communities with groundwater protection, describing the extent and causes of groundwater pollution, assessing drinking water quality, and working on groundwater policy. More information can be found at *https://www.uwsp.edu/cnr-ap/watershed/*.

Well Water Testing & Outreach

In calendar year 2021, the center helped 6,323 households test their water in conjunction with the UW-Stevens Point Water and Environmental Analysis Laboratory along with partners in county Extension offices, county health departments, and county land conservation departments. Well water testing programs were conducted in the following counties: Dodge, Sauk, Green, Chippewa, Kewaunee, Monroe, Sheboygan, Richland, Vernon, Crawford, Burnett, Waushara, Marquette, Polk, Calumet, Trempealeau, Taylor, Pierce, St. Croix, and Douglas. Many of the educational programs had to be conducted via online webinars rather than in-person meetings. In-person educational programs have resumed for programs that have taken place in 2022.

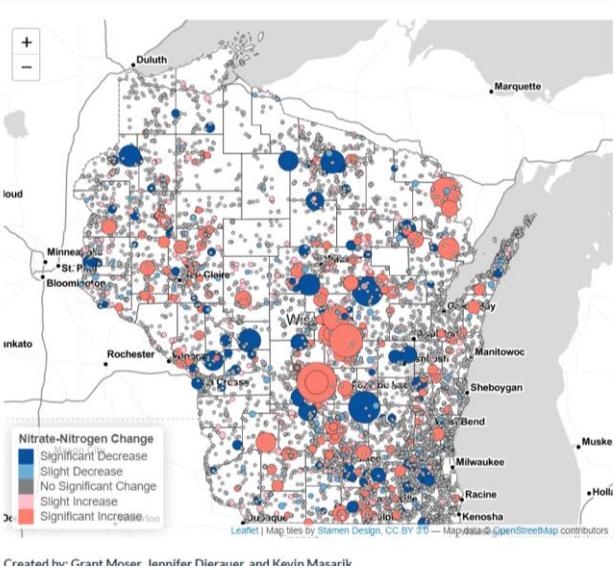


Water Quality Database

The Groundwater Center maintains a database of private well testing data from the Water and Environmental Analysis Regional Laboratory at UW-Stevens Point and conducts drinking water education programs. There are currently more than 875,000 individual test results for approximately 122,605 samples throughout the state. Chemistry data include pH, conductivity, alkalinity, total hardness, nitrate-nitrogen, chloride, saturation index, coliform bacteria, an atrazine screen, various metals and minerals including arsenic, lead, and copper. The database primarily covers the period 1985 to the present. The database can be queried, making it an easily accessible source of information for local communities and groundwater managers.

Interactive Wisconsin Well Water Quality Viewer

In July 2012, the Groundwater Center made publicly available an online mapping tool that allows people to search for groundwater quality information. The tool incorporates private well water data from the center's database, the Wisconsin Department of Natural Resources (DNR) Groundwater Retrieval Network and the Department of Agriculture, Trade and Consumer Protection. In 2014, data from the Eau Claire County Health Department were also integrated. *Summary maps* are available for 14 different water quality parameters and can be viewed or summarized into a table at a county, town or section level detail. Updated in 2019 to include nitrate/arsenic data from DNR well testing requirements for new wells and/or well pump work it now includes data for over 200,000 samples: with 105,381 samples from Extension efforts. It allows users to see water quality in their community and other parts of Wisconsin. In 2021, the Viewer was accessed by 7,509 people. The viewer was recently updated to include data thru December 31, 2021.



Nitrate in Groundwater

The Center launched a new app that investigates nitrate trends in Public Water Supply Systems. Using data from public water systems (i.e. Municipal, Other-than-Municipal, Transient, Non-community, and Non-transient, Non-community) the app summarizes publicly available data which can be viewed spatially or by Wisconsin Unique Well Number. The data reveal that 89.4% of wells have no trend, 6.8% have an increasing trend, and 3.9% have a decreasing trend. The app can be found online at: *https://shiny.theopenwaterlog.com/nitrate_trends/*

The Center is also investigating the impact of various cropping practices on groundwater quality in the Central Sands Region. Using a combination of lysimetry and wells, the study is collecting year-round data to better understand the timing of nitrate leaching losses from various crops. Because many leaching studies often focus only on the growing season, this data set will provide important insight into inter- and intra-annual variability of leaching that is necessary to calibrate and validate nitrate leaching models. An additional project was started in 2020 looking at the use of inter-planting to reduce nitrate leaching losses below commercial potato production. The work is a collaboration with Dr. Chris Kucharik and

The Little Plover River, one of the many streams in the Central Sands region affected by increased pumping. Photo: UW WRI.

students of his Lab at UW-Madison Department of Agronomy.

Central Wisconsin county-based volunteer streamflow monitoring

In a joint project with five county conservation offices and the DNR, the center launched a program that provides citizen volunteers with professional-grade streamflow monitoring equipment. This is part of an effort to better understand water conditions in the Central Sands Region affected by increased pumping. Staff members worked with county staff to recruit and train volunteers. Currently, staff are coordinating with 10 citizen volunteers to measure baseflow at 70 sites throughout the Central Sands Region. A quality control procedure is in place to independently verify a percentage of each citizen volunteer's measurements to ensure consistency and accuracy; results are extremely encouraging. These volunteers fill a large gap in baseline monitoring data of stream flow in the area.

Chemical Tracers for Identifying Sources of Groundwater Nitrate-Nitrogen

The center continues to refine chemical analysis methods for a suite of human wastewater tracers and agricultural pesticide metabolites to help trace the source of elevated groundwater nitrate concentrations in a well. This method study has resulted in a technique that has been applied to wells in Adams, Portage, St. Croix, Dunn, and Chippewa counties. Center staff worked with the DNR and the Wisconsin Department of Health Services to develop drinking water advisory levels for some of the compounds detected. Results from this study have been presented at the Wisconsin American Water Resources Association meeting and are available in a final report on the Groundwater Center's website.

PFAS in Private Wells

The Center is partnering with the Wisconsin Department of Natural Resources and Wisconsin State Laboratory of Hygiene on a statewide testing project of private wells for Per- and polyfluoroalkyl substances. Four limited-term employees hired by the Center will collect samples from up to 450 private wells selected by the DNR. The data will collect important data on ambient levels of these compounds in groundwater and private wells.

Groundwater and Lakes

The center is working with several Wisconsin counties on lake management planning that incorporates groundwater flow modeling and groundwater in hydraulic and nutrient budgets. These studies are useful ways to communicate the connection between groundwater and surface water resources and highlight the need for protecting groundwater quality. Ongoing center research includes the movement of phosphorus from septic systems and the influence of nitrogen on lakes.

5-Year County Well Water Quality Inventories

Starting in 2019, the Center began multi-year projects with Chippewa, Green, and Sauk counties to organize *citizen-based groundwater monitoring networks* in each county. Dodge County was added in 2020. Wells will be tested for the following parameters: nitrate, chloride, alkalinity, pH, hardness, and conductivity. The goal is to test the same wells for five years in a row for the purposes of understanding trends in rural groundwater

quality over time. By testing the same wells annually, Center staff will be better able to assess where/why groundwater quality changes and what characteristics and/factors can be used to predict changes in well water quality over time. County-wide summary statistics are fairly consistent for all parameters from year to year. Individual wells however tend to have greater variability. Future years will investigate what factors contribute to variability/trends in individual wells.

County	Year		Alkalinity	Chloride	Conductivity	Nitrate-Nitrogen	pH	Total Hardness
		n	mg/L as $CaCO_3$	mg/L	umhos/cm	mg/L		mg/L as $CaCO_3$
Chippewa	2019	79	62.1	22.9	256	5.0	6.78	96.2
	2020	79	66.6	24.1	274	4.9	7.33	91.7
	2021	79	69.3	24.8	268	4.9	6.95	100.7
Dodge	2020	354	333.0	34.0	792	1.7	8.03	383.1
	2021	354	339.3	34.4	783	1.5	8.07	348.1
Green	2019	307	304.6	19.1	649	5.4	7.52	341.9
	2020	307	298.6	18.9	665	5.8	8.12	340.5
	2021	307	307.2	19.1	661	5.8	8.09	346.3
Sauk	2019	351	207.4	16.6	470	4.2	7.58	233.2
	2020	351	204.9	17.1	479	4.3	8.02	227.3
	2021	351	214.8	16.8	474	4.1	7.82	233.8

Policy

The center continues to play pivotal roles in a number of state groundwater issues. Working with partners in the private and public sectors on groundwater quantity policy and law has been a continuing priority. Center staff routinely present information on the science of groundwater quality and groundwater pumping and associated impacts to local and state government officials. Staff recently participated in the Wisconsin DNR Central Sands Lake Study and the NR151 Nitrate Technical Advisory Committee.

Recent Publications and Reports (past 5 years)

Nitka, A.L., DeVita, W., McGinley, P.M. 2019. Evaluating a Chemical Source-Tracing Suite for Septic System Nitrate in Household Wells. Water Research 148(1):438-445 http://dx.doi.org/10.1016/j.watres.2018.10.019

Nitka, A.L. and P.M. McGinley. 2017. Investigating the impact of nitrate contamination on uranium and other elements of emerging concern in Wisconsin groundwater. Report to the Water Resources Research Institute in partial fulfillment of UWS Project WR16R002.

Luczaj, J., and K. Masarik. 2015. Groundwater quantity and quality issues in a water-rich region: Examples from Wisconsin, USA. *Resources* 2015 4:323-357. *doi*:*10.3390/resources4020323.*

Masarik, K., M. Mechenich, A. Nitka and G. Kraft. 2018. Portage County Well Water Quality – 2017. Report in partial fulfillment of Portage County Project.

Masarik, K.C. 2016. Design of a field-scale approach for evaluating nitrogen management practices impacts to groundwater. Report in partial fulfillment of DNR Project #15_BMP_01.

For more information on the Central Wisconsin Groundwater Center:
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University of Wisconsin-Madison Division of Extension: Natural Resources Institute's (NRI) Land & Water Programs

The Division of Extension Natural Resources Institute's (NRI) Land & Water Programs include state and local specialists addressing water resources, land and water conservation, forestry, conservation professional training, citizen engagement, and volunteer monitoring. NRI also coordinates a number of regional and national programs addressing water resources and water-education initiatives related to groundwater.

NRI Regional Water Programs and Conservation Professional Development

NRI coordinates the *North Central Region Water Network (NCRWN)*, a 12-state collaboration among Land Grant universities, including partnerships with state and federal agencies across the Upper Midwest region. Through this network, Extension researchers and educators share programs and coordinate on an array of water resource issues, including groundwater quantity and quality. Currently, multi-state teams are active around soil health, watershed leadership, harmful algal blooms, drought, climate, and green infrastructure.

NRI also coordinates the *Conservation Professional Training Program*, which develops and hosts multi-state professional development for conservation professionals. Wisconsin programs have included issues of conservation lands management such as manure management and fractured bedrock geology, including:

- Classroom and field training for local elected officials (town, county) both on the basic geology of local resources and localized research on groundwater quality and land use impacts in both the northeast and southwest regions of the state.
- Training public- and private-sector professionals to help farmers more effectively manage manure and commercial nitrogen fertilizers that can negatively impact groundwater.
- Training for manure applicators on manure application in karst areas.
- Providing conservation planning training and farmer training that includes karst issues.
- Offering projects that help water resource managers understand farmer awareness of, and capacity to adopt, conservation practices that are most likely to fit into farm management systems.

NRI Water Outreach and Education

The *Water Action Volunteers* stream monitoring program educates both children and adults about stream ecology and stream health. Volunteers continue to monitor more than 500 stream sites statewide for a variety of parameters, including stream flow, which is directly affected by groundwater. Volunteer-collected data is helping to characterize water

quality and quantity across the state and to identify streams where impairments may exist. This program engages volunteer monitors in partnership with schools, nature centers, and many others to provide educational experiences and important data regarding streams and hydrological systems.

The *Wisconsin Master Naturalist* program, active since 2012, follows a train-the-trainer approach to engage Wisconsin citizens in resource management. The course curriculum covers a variety of natural resources issues specific to Wisconsin, including groundwater quality and use. Certified volunteers are expected to provide 40 hours of natural-resource-related service annually to Wisconsin host organizations, such as nature centers, state parks, or museums. Areas of service include education/interpretation, stewardship, and citizen science. The Wisconsin Master Naturalist Program has resulted in over 178,000 volunteer hours providing nearly $5.1million dollars in value to the state since the program began. Fifty-eight host organizations have partnered with the program by having 162 individuals trained as instructors who have trained 1,115 volunteers statewide. There is a presence of Master Naturalists in 64 of Wisconsin's 72 counties. The course provides a broad overview of Wisconsin's natural resources and the processes that affect them. This program continues to grow in cooperation with partners across Wisconsin.

Northland College Professor Tom Fitz teaching Master Naturalist volunteers about artesian wells found in northern Wisconsin.

Master Naturalist volunteer providing water quality monitoring on a stream in Rock County.

Regional Natural Resource Education Program

Extension's Natural Resources Institute cooperates on community-focused educational programs with other state agencies involved with water resources and natural resource issues. The *Regional Natural Resources Education Program* uses locally based natural resource educators to develop and conduct programs that reach local and statewide audiences by accessing state-level support for educational material development and program evaluation. The educational programs address a broad range of groundwater-related topics, including drinking water, threats to groundwater quality, impacts of land-use changes, and land management decisions on groundwater quantity, information about localized groundwater problems such as karst geology, water conservation, and efficiency, along with a variety of other issues associated with nutrients in surface water and groundwater. Educators have actively engaged with and facilitated the development and growth of farmer-led groups that learn about and implement conservation practices designed to address a host of water quality issues.

For more information on NRI/Land & Water programs related to groundwater:
Contact Chad Cook, NRI Associate Director of Outreach
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University of Wisconsin Nutrient and Pest Management (NPM) Program

Mission Statement

The University of Wisconsin's Nutrient and Pest Management (NPM) Program works with farmers, researchers, agricultural professionals, and citizens to provide research-based agricultural nutrient and pest management education on crop production practices that protect water quality, farm profitability, and resilient landscapes.

Overall, in 2021, the NPM program staff collectively educated 13,225 people, at 548 events, giving 189 unique (original, first-time) presentations. In addition, they provided 16,573 individual consultations via email, phone, and in-person contacts. Educational products developed in 2020 include 36 videos, 47 print publications, and 125 nutrient management training manuals.

NPM Program outreach products are available for viewing and downloading at: https://ipcm.wisc.edu/

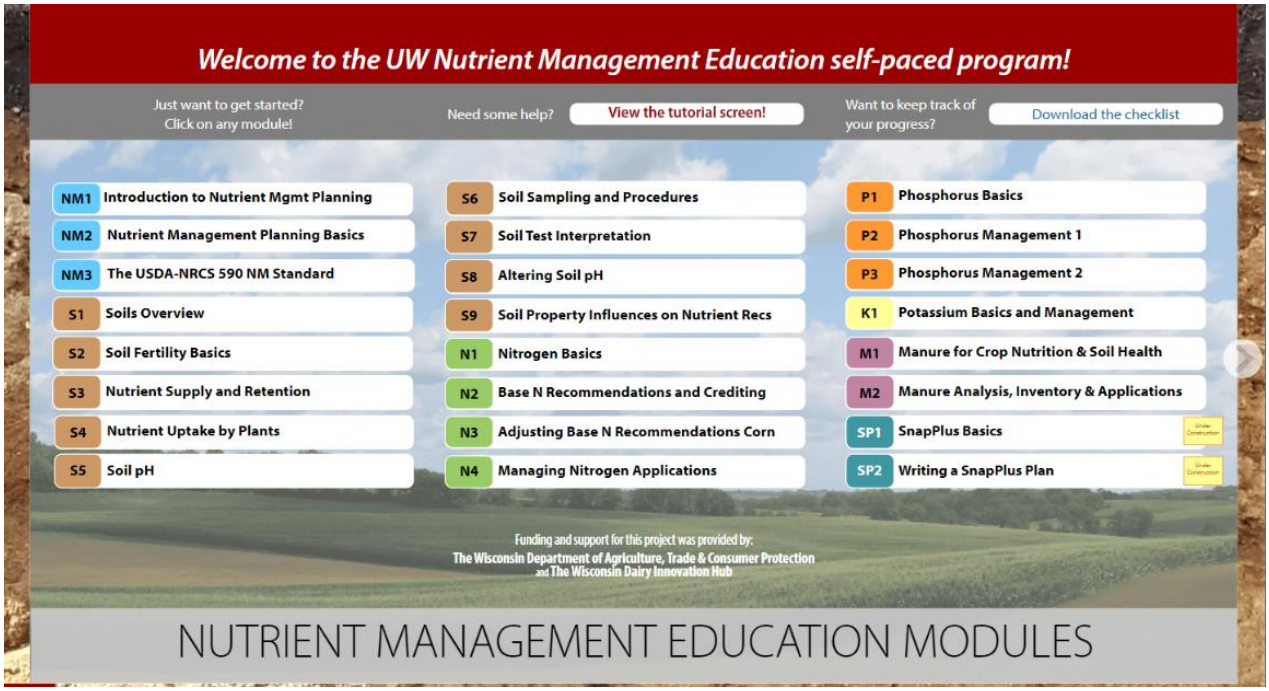
Nutrient Management

The NPM Program is part of a team that develops, distributes, evaluates, and implements nutrient management education programs. Partners include University of Wisconsin-Madison College of Agriculture and Life Sciences (UW-CALS) faculty/staff; county-based UW-Extension staff; land & water conservation departments; Wisconsin technical colleges; the Wisconsin Department of Agriculture, Trade and Consumer Protection; and the U.S. Department of Agriculture-Natural Resources Conservation Service, along with private-sector agri-businesses and Wisconsin farm producers. Activities include:

- *Nutrient Management Farmer Education Curriculum* (NMFEC) development and implementation. The NMFEC is an essential tool used throughout the state to teach farmers about crop nutrient management practices that improve profitability and reduce adverse impacts of nitrogen and phosphorus pollution. The NPM Program staff maintain, update, produce, distribute, and implement the NMFEC. The curriculum combines classroom instruction, individual consultation, and on-farm field trials to deliver education on the preparation and understanding of farmer-written nutrient management plans. The curriculum is delivered statewide through collaborations with partners identified in the previous paragraph. Participation in a NMFEC project is the **only** mechanism for Wisconsin farmers to become certified to prepare their own nutrient management plans.

Cumulative accomplishments numbers from 2000 to 2021 show that as a result of local delivery of the curriculum, more than 9,178 producers farming approximately 2,683,770 acres in 55 counties have received in-depth education on nutrient management planning. In 2021, approximately 362 farmers operating about 118,745 acres in more than 20 Wisconsin counties added to this accomplishment list. Data are currently being collected for 2022 accomplishments.

- *Release of a new platform and updated content for the NMFE Curriculum*. An online, video-based instruction version was developed in 2021 and released in early 2022. The new NMFE allows for self-paced learning by users. The new curriculum is available at: https://nmfe.webhosting.cals.wisc.edu/. (*Please allow a few minutes for the initial*



download.) Content of the digital curriculum is displayed in a modular format. Each module deals with a specific component of a nutrient management plan and features multiple, short, instructive videos along with linked resources. This project was in response to challenges with the traditional delivery of the NMFE curriculum including COVID-19 restrictions as well as staff and budget reductions. This digital remote delivery method will: i) Eliminate or greatly reduce the need for physically close instructor-student contact, ii) Allow for self-paced, self-instruction, and iii) Increase the number of Wisconsin farms possessing and implementing NM plans. Support for this project is provided by WDATCP and the UW-Madison Dairy Innovation Hub.

- *SnapPlus nutrient management planning software* assistance and refinement in conjunction with the SnapPlus team (UW-Madison Soil Science). NPM staff assist in developing educational online videos (11), updating the SnapPlus online help system, refining output reports to meet the needs of end users and the creation of a SnapPlus training manual with more than 125 copies requested and delivered in December of 2021. In addition to creating SnapPlus educational products, NPM staff actively train farmers, agronomists, and others to use SnapPlus. In 2020, NPM staff members continue to assist the SnapPlus team in the development of a new SnapPlus user interface as well as quality control reviews of the software program.

- *Educational support to Wisconsin watershed projects*. Activities include coordination and delivery of individual nutrient management plans, on-farm demonstrations (nutrient crediting, nitrogen rates for corn, soil health, cover crops, soil erosion control, etc.). Support activities include planning, advice, coordination, grant preparation, and reporting. In addition, NPM staff serve on the selection committee for DATCP-sponsored farmer-led watershed projects. NPM Program staff serve as key members of watershed projects (producer-led, federal NRCS, and other) in 22 watershed projects in 39 Wisconsin counties.

- *On-farm demonstrations, field plot research and subsequent educational programs* on various topics including: adaptive nitrogen management for corn, cover crops, conservation tillage, manure applications, etc. occurred in six counties in 2021.

Pest Management

NPM, in conjunction with numerous partners including UW-Madison-CALS faculty, county-based UW-Extension, the UW Integrated Pest Management (IPM) Program, and others, delivers timely educational programming on topics associated with pest management. Activities include:

- *Waterhemp weed control project* involves statewide field trails evaluating control techniques for herbicide-resistant waterhemp. Waterhemp is a very aggressive weed that is wreaking havoc across the nation's cropland fields. In 2021 NPM conducted on-farm research waterhemp trials in Dane, Grant, Shawano, and Oconto counties.

- *Soil conservation and weed management.* NPM working with the UW-Madison Dept. of Agronomy conducted on-farm research aimed at managing weeds while improving soil conservation. These trials look at using cover crops, no-till, residual herbicides, and system-based programs for the management of waterhemp and other troublesome weeds in Wisconsin.

- *Strategies for avoiding herbicide resistance in weeds.* The NPM program delivers educational outreach materials and trainings to Wisconsin producers and agri-businesses on strategies for avoiding the development of herbicide resistance in weeds. Strategies include awareness and diversification of herbicide modes of action used on a given farm/field, equipment sanitation to avoid transport of weed seeds, and identification of weed species likely to be resistant to popular herbicides.

- *White mold and waterhemp management using winter rye.* NPM conducted on-farm research aimed at managing white mold and waterhemp in soybean while improving soil conservation. These trials looked at using winter rye vs. conventional approaches to managing white mold on farms in Wisconsin.

- *On-farm roller crimper studies.* Three on-farm studies were conducted to investigate the on-farm utility of using the rye/roller-crimper system for white mold and waterhemp management while reducing pesticide inputs. Locations included Lafayette, Portage, and Calumet Counties.

Cropping Systems

- *Cover crops research, education and outreach.* NPM partnered with county Extension educators, USDA-NRCS, County Land Conservation Departments, non-governmental organizations, and CALS specialists to deliver cover crop education programs in person and virtually across the state and Midwest. Activities included on-farm field days, on-farm research and demonstration, development of educational videos, factsheets, publications, and training farmers and agronomists. NPM outreach specialists provided active leadership in the Wis. Cover Crops Conference and Cover Crops Research and Outreach Project (CCROP). Cover crop demonstration and research plots were continued at Peninsular, Lancaster, and Arlington Agriculture Research Stations.

- *Soil health education.* More than 70 soil health presentations were given in-person and virtually to farmers, lake & watershed groups, tribal communities, and youth throughout the state, region, and nation. NPM staff worked closely with community and farmer-led watershed groups to develop demonstration/research projects and field days to highlight the impact of agricultural practices on soil health and water quality. NPM staff, with Extension and agency collaborators, defined soil health indicators for cranberry production systems in Wisconsin. Additionally, NPM staff assisted the Wisconsin Natural Resources Conservation Service in delivering soil health education to new and existing agency staff, attendees at Farm Technology Days, and high school agriculture educators.

- *Badger Crop Connect.* NPM staff were part of a team of educators within the Crops & Soils Program of the Division of Extension that organized and delivered a new series of webinars containing timely Wisconsin crop management information from March through October 2021. These webinars were a successful alternative to in-person fields days. Three NPM staff delivered four unique presentations at four different sessions. Collectively, there were over 1,122 viewer logins for these discussions.

- *Healthy Grown / Healthy Farms.* NPM working cooperatively with the WI Potato and Vegetable Growers Association (WPVGA) has developed a national model of sustainable production systems, exemplifying integrated pest management. In addition, the program includes a nationally recognized ecosystem restoration effort. In 2021, ten growers were certified and over 12,800 acres of fresh market potatoes (about 40% of Wisconsin's fresh market acres) were verified as "Healthy Grown." NPM has worked with the WPVGA to expand "Healthy Grown" to carrots and onions.

- *Water quality and conservation expansion programs*. NPM staff have worked to expand water quality programs with state potato and vegetable growers. The inclusion of water modules into Healthy Grown was developed and piloted in 2021. This led to an expanded role for NPM staff including the WDNR proposed NR 151 rule change comprehensive economic analysis project, outreach coordination for the USDA-SCRI Potato Soil Health Project, work with the Central Wis. Farmer Cooperative Producer-Led Watershed, lead for the Central Wis. Water Quality Working Group, and continued work as a liaison with the Water Task Force.

- *First Nation sustainable food production and food sovereignty initiatives*. Through programming efforts of the College of Menominee Nation, Menominee Indian Tribe, the Stockbridge-Munsee Community, and Wisconsin Farm Bureau, NPM's Dr. Jamie Patton provided educational outreach on culturally-relevant, sustainable food production practices to indigenous communities in the Great Lakes Region, as well as northeast Wisconsin non-native agricultural producers. Additionally, NPM supported youth STEM education by providing multiple presentations on environmental topics to the College of Menominee Nation-Sustainable Development Institute's Summer Sustainability Leadership Cohort, a program for Menominee high school youth.

- *UWEX Agricultural Institute Climate Change Team.* The NPM Program is part of a leadership group guiding the UWEX-Agriculture Institute Climate Change Education Team. The team's mission is to provide professional development and educational resources to enhance the ability of Extension agricultural educators to address current and expected challenges associated with climate change. In 2021, three professional development webinars were held, attended by 60 educators and specialists from three UWEX Institutes.

Outreach and Communication

- *Mobile applications*. The NPM Program creates mobile applications (apps) for hand-held devices (Apple and Android). Maintenance and updating of the NPM Program's apps occurred in 2021. Currently available mobile apps include: *Tarspotter*, *Sporebuster, Manure Tracker, Sporecaster, Nitrogen (N) Price Calculator, Corn N Rate Calculator, Integrated Pest Management Toolkit, Corn Crop Calculator, Manure and Legume Nutrient Credit Calculator*, and *BeanCam* (*https://ipcm.wisc.edu/apps/*). Collectively, these apps have been downloaded by more than 140,000 users from across the world. All apps are created in collaboration with UW-Madison faculty and are promoting agricultural best management practices.

- *YouTube videos*. The NPM Program produced 36 new videos on a range of crop management topics in 2021. Over 330 YouTube educational videos featuring UW-Madison-CALS specialists have been prepared and released by the NPM Program over the past nine years. A complete listing can be found at *https://www.youtube.com/user/uwipm*. A conservative estimate of the number of views is greater than 1,200 worldwide per day with over 2.2 million total views as of November 2021.

- *Wisconsin Crop Manager newsletter and IPCM website*. The NPM and IPM Program website delivers the popular *Wisconsin Crop Manager* newsletter featuring contributions from faculty and staff across UW-CALS departments. *Wisconsin Crop Manager* is produced weekly during the growing season with semi-monthly and monthly releases during the winter months. The weekly e-mail distribution list contains 1,244 recipients, with 14,000 PDF downloads in 2021. Available online at: *https://ipcm.wisc.edu/wcm/*.

- *NPM publications*. The NPM Program has a long history of collaborating with CALS faculty specialists to create timely, pertinent, high-quality publications promoting the adoption of agricultural management practices to improve water quality and farm profitability. In 2021, 47 new publications were produced. Formats range from simple pocket-sized cards to extensive manuals and workbooks. NPM staff roles include author, editor, and designer. A listing of NPM's print publications can be found at *https://ipcm.wisc.edu/downloads/*.

- *NPM Resource Highlights.* An online, digital newsletter created in 2020 is sent monthly to the UWEX Agricultural Institute (AI) list serve. Its purpose is to inform AI affiliates of new and existing NPM Program resources that are seasonally pertinent. Publications, videos, mobile applications, etc. are featured. The original intent was to inform new county educators of NPM Program educational products; however, feedback from UW/UWEX faculty and staff indicate that they, also, find the information useful in their local programming efforts.

- The NPM Program won three Certificate of Excellence Awards in 2021 from the American Society of Agronomy (ASA) Extension Education Materials Competition. The NPM Program has won a total of 24 awards from ASA in ten years! Year 2021 awards include: *Small Grains in Wisconsin* (award category: pubs. <16 pages); *Tarspotter Corn Disease Forecast Tool (*digital decision aids); *Bumper Crops video series* (audiovisuals).

For more information on the NPM program:
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Wisconsin State Laboratory of Hygiene (WSLH)

At the Wisconsin State Laboratory of Hygiene (WSLH), a great deal of effort is focused on identifying and monitoring chemical and microbial contaminants in groundwater through testing, emergency response, education and outreach, and specialized research. The activities related to groundwater span several departments at WSLH. The mission of the WSLH is to protect the health of drinking-water consumers by providing analytical expertise, research, and educational services to the scientific and regulatory communities and the public.

The chemical and microbial groundwater contaminants routinely tested include all contaminants regulated by the federal Safe Drinking Water Act, as well as many emerging contaminants that appear on the USEPA Contaminant Candidate List. Examples include: fecal indicators (total coliform, *E. coli*, coliphage, *Bacteroides* spp., *Rhodococcus coprophilus*, sorbitol-fermenting Bifidobacteria), *E. coli* O157:H7, toxigenic *E. coli*, Salmonella, waterborne viruses (norovirus), human-adenovirus, parasites

(Cryptosporidium, Giardia, and microsporidia), radioactivity, inorganic compounds (mercury, nitrate, arsenic), and organic compounds (atrazine, PCBs, PBDEs). PFAS contamination has gained significant attention and significant resources are being directed toward testing and outreach to support the many PFAS related efforts. The water microbiology section of the WSLH currently has molecular capabilities to analyze for human adenovirus and distinguish between bovine and human *Bacteroides* spp. as part of the laboratory's toolbox approach to microbial source tracking in groundwater.

In addition to routine testing of fecal indicators and emerging contaminants, the WSLH now employs a "toolbox" of microbial and chemical source-tracking assays. Microbial and chemical source tracking is used to determine sources of fecal contamination in water, whether from human or animal sources, using multiple microbial and chemical agents. The data are then used for making management decisions regarding control of fecal pollution of groundwater.

Another important focus of the WSLH is emergency response to incidents involving groundwater. For example, WSLH works with the DHS and the DNR to investigate outbreaks of illnesses of unknown (possibly food or water) origin. Staff provides background information on the outbreaks for local public health officials, local media, and the general public. WSLH also responds to spills and incidents and supports state agencies in remediation and emergency cleanup activities.

WSLH also provides educational and outreach activities related to groundwater and drinking water including (1) instructional consultations for well owners and well drillers, (2) assistance and consultation for municipal water supply operators, and (3) tours for a variety of international, educational, regulatory, and governmental groups. Staff members have developed publications related to drinking water, including a well water activity sheet, "*Test your well water annually"* brochure, and other well water testing promotional materials. Staff members present papers at a variety of conferences and symposia and publish research findings in professional journals.

Summary of Groundwater-Related Work at WSLH

Organic Chemistry Section

- The State Laboratory has developed and is validating methods for measurement of PFAS chemicals in various matrices, including groundwater/drinking water. Significant coordination with state and federal partners occurs to ensure appropriate certifications are in place, which PFAS compounds to focus on, and matrix specific challenges such as limits of detection. As with many labs, capacity challenges exist so better and quicker ways to measure PFAS are continually being pursued. The State Laboratory is happy to partner with others and share information as appropriate to collectively advance understanding about these issues. State and Federal efforts are ongoing to support drinking water and groundwater testing for PFAS compounds.
- Interpretation of GC-MS and LC-MS analysis of petroleum compounds is done to aid in fingerprinting possible sources of contamination. Other source tracking tools and lists of compounds (human sources, animal sources) are also provided to assist in understanding source, fate, and transport of contaminants.
- Analysis of pharmaceuticals, personal care products, and antibiotics as tools to indicate pollution from humans and animals. This analysis in conjunction with the

Microbial Source Tracking "Toolbox" is used to support various activities toward groundwater protection and management.

Chemical Emergency Response Section

- The WSLH serves as the only public health emergency preparedness-supported chemical response laboratory in Wisconsin. The lab has extensive capabilities for testing human exposures to priority chemical agents, provides sampling materials and guidance for first responders, including hazardous material, drinking water, and natural resource entities, and performs any needed testing of environmental samples related to chemical incidents. One facet of this support has been the development of a drinking water collection kit, tailored to allow appropriate collection for assessing a wide range of chemical and microbiological contaminants in drinking water. These kits have been provided to all drinking water utilities serving more than 3,000 people, as well as to public health and other appropriate agencies. The emergency kit continues to be deployed to assist in characterizing a possible contamination and the system worked as designed.

Water Microbiology Section

- 2021 and 2022 continues to see the WSLH performing significant work with Sars-CoV2 (COVID) in wastewater. COVID in Wastewater has garnered significant attention and continues to be relevant and add value. This work was and continues to be a joint effort between the water microbiology section and environmental toxicology. COVID in wastewater has been a useful tool for communities to understand levels of the virus on a community level, thus indicating overall levels or trends of the virus on a broader scale.
- Source assessment requirement under the Revised Total Coliform Rule - WSLH continues to implement a scientifically based well assessment for wells testing positive for coliforms. This project is to develop and test a suite of microbial organisms that can determine the source of contamination by collecting a large volume sample using a hollow fiber ultra-filtration system.
- WSLH is researching changes to the fecal source tracking toolbox by implementing species-specific PCR assays for human, bovine, swine, and poultry Bifidobacteria; improving the PCR primer sets for human and bovine Bacteroides spp.; and determining the feasibility of using pepper mild mottle virus to determine human contamination in groundwater. The research includes collecting fecal samples from animals throughout the state to determine sensitivity and cross reactivity for microbial sources of contamination.
- As a part of a larger laboratory-wide preparedness program, WSLH is prepared to offer appropriate microbial water quality testing when needed. WSLH is a member of the Environmental Response Laboratory Network and the Water Laboratory Alliance for both chemical and biological response. This involves participation in nationwide preparedness drills coordinated by the Centers for Disease Control and Prevention in conjunction with the U.S. Environmental Protection Agency.
- The WSLH Flow Cytometry Unit coordinates and distributes samples for the only Cryptosporidium Proficiency Testing Program (PT) available in the United States. This WSLH program supports environmental laboratories testing water samples for the presence of this parasitic protozoan under the Long Term 2 Enhanced Surface Water Treatment Rule. The program has been designed to provide water-testing laboratories and accreditation agencies with a means of assessing a laboratory's performance of U.S. EPA Method 1622/1623. The program is accredited under ISO

17043 "general requirements for proficiency testing" and distributes samples twice annually. The program operates with support from the WSLH Water Microbiology Department, which evaluates the robustness of the parasites suspensions prior to and following distribution to participant laboratories.

- The Water Microbiology Section of the WSLH Environmental Health Division has developed a suite of testing and sampling methods called Large Volume Sampling (LVS) that is designed to detect organisms that can be present in low concentrations.

Inorganic Chemistry Section

- Instrumentation is in place to measure isotopic ratios of certain metals (i.e. lead) to identify the source of the particular metal, be it the source, piping, etc. Each case is different, but it is possible to deploy this technology to better elucidate the source of a metal in drinking water or other matrices. Lead and mercury are good candidates for testing in these regards. Radium in groundwater is another candidate for the application of a potentially better tool.
- A variety of nutrients are routinely measured in drinking water, surface water, and groundwater. People with health concerns regarding their drinking water, such as nitrates, can submit samples for evaluation. Results are sent to the clients and the DNR for their database. The DHS has worked with WSLH at the county level to provide drinking water kits to families with newborns to monitor for nitrates in well water.
- Most types of metals are also measured. Those of health concern and public interest, such as arsenic and hexavalent chromium, are important in monitoring because they have been associated with specific geological formations and conditions in northeastern Wisconsin.
- Ancillary inorganic tests are routinely performed to measure chloride, sulfate, pH, alkalinity, and conductivity—properties that are important in controlling the chemical conditions for groundwater systems.
- As with other sections of the WSLH, the Inorganic Section responds to both spills that would affect surface water and groundwater. The lab has worked extensively with both DNR and DHS to identify contaminates in well water that may have had surficial origins. The WSLH recently has added multi-collector ICPMS instrumentation that can be used to measure isotopic fingerprints of metals to source-track their origin.
- The inorganic section has a dedicated trace-level clean lab that routinely measures metals or elements in water at the parts per trillion (ppt) ranges for unique applied low-level research questions and monitoring.
- The WSLH works with and receives samples from the U.S. Geological Survey, researchers at UW campuses, and the Wisconsin Geological and Natural History Survey on specialized groundwater projects. The lab also routinely measures samples from drinking water utilities that rely on groundwater.

For more information on the WSLH:

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